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Final Reports: Deep Autonomous Gliders for the "Autonomous Ocean Sampling Network II" Experiment - N00014-99-11049

Three new Spray gliders were constructed and five, including 2 NOAA test units, were operated throughout the AOSN intensive study month of August 2003. A team of four people deployed the array before the experiment and recovered it at the end of the one-month study. Figure 1 shows the locations of profile "stations" during AOSN II.

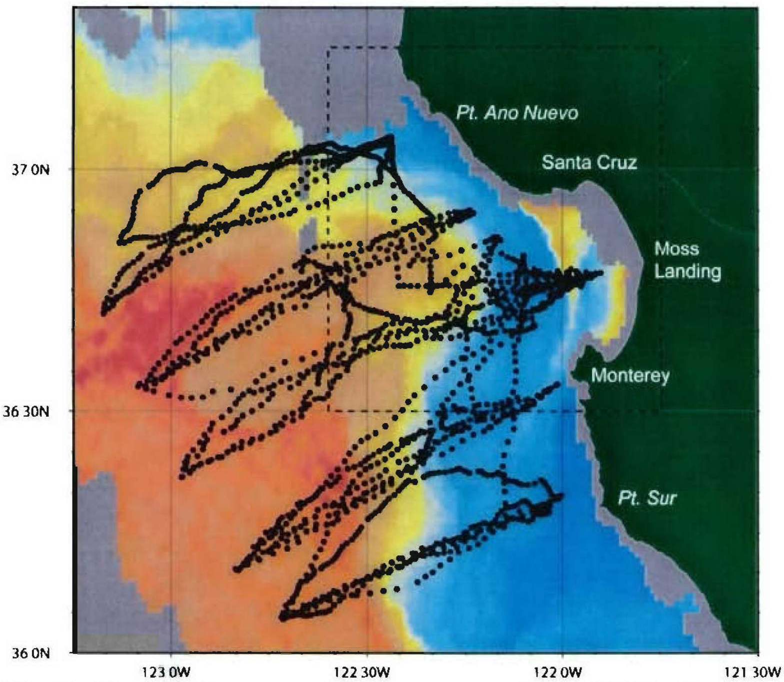

Figure 1. Array of profiles made by five Spray underwater gliders during the 30-day AOSN II experiment. Profiles of temperature, salinity, and either fluorescence or optical backscatter were typically made to 400 m with occasional deeper profiles. Target tracks were straight offshore lines but currents pushed the slow-moving gliders off their design course.

Final edited and corrected data were made available through the AOSN website in October 2003.

There were five main results from this project:

1. It was shown that Spray has matured to an operational state and that the instrument makes possible cost-effective long-term regional observing systems.

2. Comparison with the Slocum glider has shown the strengths of the two designs. The combination of lithium batteries (rather than alkaline cells), lower drag, and more succinct data transmission allow Spray to operate for months instead of weeks for Slocum. This greatly reduces the manpower and ship time required to maintain a glider array. The Slocum is designed to turn and change pitch more rapidly, permitting operation in shallower water. The Precision Measurement Engineering conductivity sensor used on Spray was subject to step changes in calibration, apparently caused by impact with biological particles. A more stable conductivity cell will be needed for future operations.

3. Direct velocity observations, deduced from the difference between dead reckoning and navigation, disclosed a surprisingly strong California Undercurrent. Figure 2 shows the average velocity between the surface and 400 m measured between 3 August and 10 August 2003. The figure shows a strong

Undercurrent flowing to the northwest, with depth-averaged speeds up to 25 cm/s.

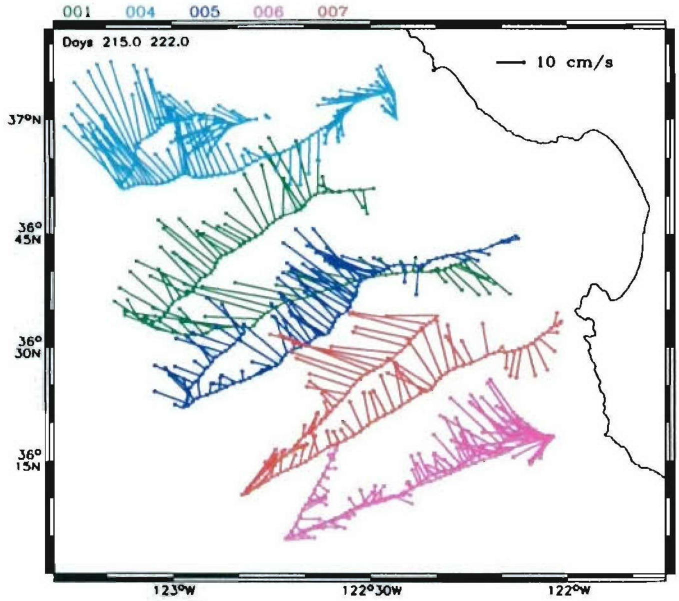

Figure 2. Average velocity between 0 and 400 m depth offshore from Monterey Bay. Each color represents a different glider. The period covered, 3-10 August 2003, is at the start of the experiment so that the green and red lines show the gliders dispersing from their deployment at 36.7°N, 122°W. Offshore currents to the northwest are the California Undercurrent, which frequently exceeds 20 cm/s. Equatorward flow is apparent closer to shore.

4. The scales of spatial and temporal variability (Figure 3) are smaller than anticipated in the experiment design. The scales of about 20 km and 2 days means 10-20 gliders would be needed to map the offshore region occupied by Spray gliders.

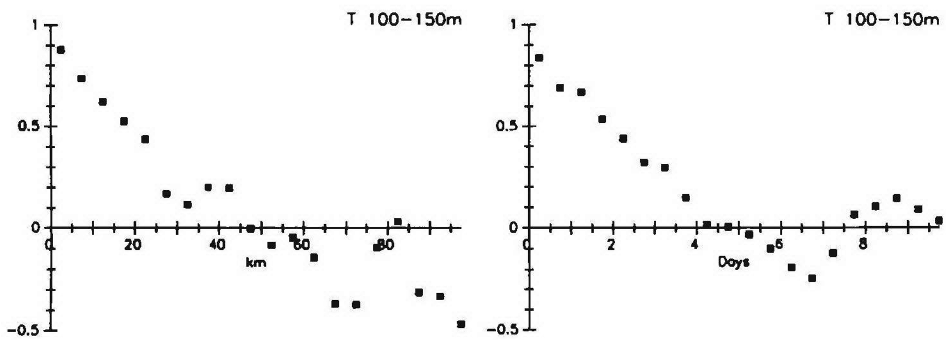

Figure 3. Spatially (left) and temporally (right) lagged correlation of the average temperature between 100 and 150 m depth showing characteristic scales of 2 days and 15 km.

5. Comparison of all temperature observations (Figure 4) shows how well the ROMS data assimilating dynamical model described the field of temperaure variability and also shows the impact that assimilating data had on the model-data comparison.

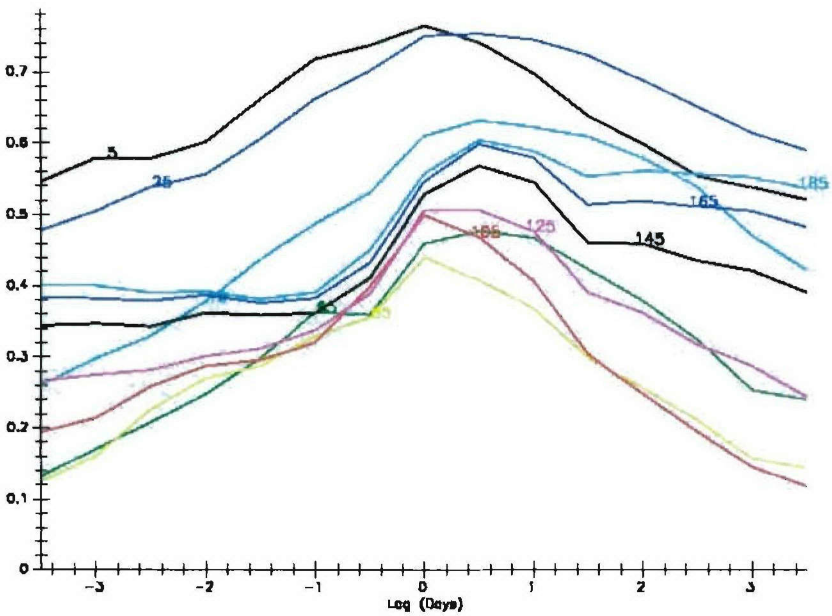

Figure 4. The correlation of ROMS temperature at time t+Lag with observations at time t, both at the same position. Correlations are for various depths as labeled. Even at the surface only 50% of the observation variance is described. At depth the impact of assimilating data is evident in the asymmetry of the correlation. The later model is better correlated with data because the model has assimilated that data.

The successful operations of Spray indicate that this underwater glider is ready for operational use. Limited operating speeds require daily, or at critical times hourly, updates of the mission parameters to adapt to currents, and sensor longevity remains an issue, but underwater gliders open new possibilities for cost-effective autonomous sampling of the ocean. Accurate sampling requires observations not to be separated by much more than correlation scales, which means that in offshore Monterey Bay one glider is, at any one time, describing about 1000 km^2

We also experimented with controlling gliders in strong currents. One approach is an exhaustive search over many possible paths to find the one that gets from point to point most quickly. If the paths span several scale lengths of the velocity field, such a search is prohibitively expensive. If the path moves forward, without doubling back, a very simple optimizing search can . We have developed a routing procedure that augments this "moves forward" search to deal with a limited number of double-back excursions. This search is being integrated into a software system that can be used to route gliders, both as they travel point-to-point to establish arrays and as they move to map a measured field.

We look forward to a real-world test of the proposed array control scheme in the 2006 and to gathering data that describes the formation and evolution of surface mixed layers near the coast.